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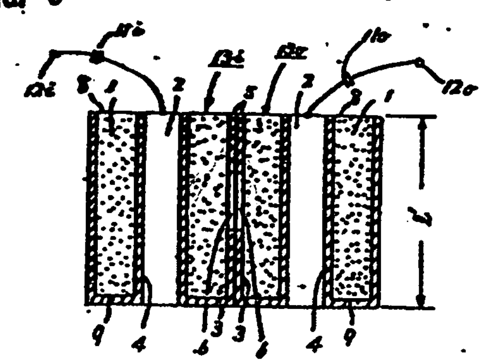
(54) Dielectric filter with a quarter wavelength coaxial resonator.

(57) A filter is formed by coupling plural resonators (13i, 13o) via an electromagnetic field. Each resonator comprises a tubular dielectric (1) having at least one flat side-surface (3), a through-hole (2) provided in the axial direction of the dielectric, an inner conductor film (4) provided on a wall forming the through-hole, and an outer conductor film (5) provided on side surfaces (7, 8, 9) of the dielectric (1), and resonates in TEM mode in the axial direction by cooperation of the inner conductor (4), outer conductor (5) and the dielectric (1) intervening between them. Each resonator further has a coupling window (6) which is formed by removing a part of the outer conductor film (5) on the flat side surface (3). The resonators (13i, 13o) are disposed so that their flat side surfaces (3) having the coupling windows (6) contact each other, and are coupled together via electromagnetic field through the coupling windows.

FIG. 5



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Semi-Coaxial Dielectric Filter

1. Field of the Invention

This invention relates to a filter used in a frequency range from VHF band to relatively low frequency microwave band.

2. Description of the Prior Art

Conventionally, this kind of filter is constructed as disclosed in the Japanese Laid-open Patent Application No. 58-9401. The structure is shown in FIGs. 1 and 2, which show a dielectric 101, through-holes 102, an outer conductor of conductive film 103 disposed on the side of the dielectric 101, inner conductors of conductive film 104 surrounding the through-holes 102, end surfaces 105 and 106 short-circuiting conductor of conductive film 107 provided on the end surface 106, coupling capacitors 108a and 108b, input and output terminals 109a and 109b, and a cavity 110. The end surface 105 is open. Therefore, two 1/4 wavelength resonant units are composed by the inner conductor 104, outer conductor 103, short-circuiting conductor 107, and intervening dielectric 101. These two resonant units are coupled together via the cavity 110, and the coupling coefficient is determined by the shape of the cavity 110. The input and output terminals 109a and 109b are electrically connected to the inner conductor 104

at the open end plane 103 via the coupling capacitors 108a and 108b, respectively, thereby making up a filter as a whole.

In such conventional construction, however, since the cavity is needed for coupling, the space occupied by the cavity is an obstacle for reducing the size of the filter. Since the dielectric to compose the filter is integral, it is impossible to evaluate each of the resonant units. If filters having different performances were required, different dielectric blocks having different shapes corresponding to such requirements must be prepared, which reduces productivity. Since the cavity for coupling is exposed outside the filter, the filter will be easily affected by the environmental conditions.

SUMMARY OF THE INVENTION

It is hence a primary object of this invention to provide a semi-coaxial dielectric filter that is small in size but is excellent in mass producibility at low cost.

It is another object of this invention to provide a semi-coaxial dielectric filter that is stable, or less susceptible to effects of the environment outside the filter.

These objects can be achieved by a filter comprising at least two independent resonators coupled to each other via coupling windows. Each of the resonators comprises a tubular dielectric having at least one flat side surface

and a through-hole in the axial direction, an inner conductive film provided on the wall forming the through-hole, and an outer conductive film provided on side surfaces of the tubular dielectric, thereby to resonate in TEM-mode in the axial direction due to cooperation of the inner and outer conductive films and the dielectric intervening therebetween. Each of the resonators is further provided at the flat side surface with at least one coupling window at which the conductive film is removed. The resonators are connected to contact at the flat side surfaces so that the coupling windows oppose to each other, thereby to construct the filter in which the resonators are coupled with each other via electromagnetic field through the coupling windows.

With this structure, the size of the filter becomes small because the size is merely the sum of the sizes of the resonators. The performances of the resonators can be evaluated independently to each other. Since the coupling coefficient can be changed by merely changing the shape or the position of the coupling window, filters having a variety of performances can be easily obtained at a low cost, resulting in high productivity. Since the electromagnetic field contributing to the filter operation is substantially distributed within the dielectric, the filter is hardly affected by the environment outside the filter.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGs. 1 and 2 are side sectional and perspective views of a conventional filter;

FIGs. 3 and 4 are side sectional and perspective views of a resonator, a construction element of a filter of this invention;

FIGs. 5 and 6 are side sectional and perspective views of an embodiment of the filter of this invention, which is a two-stage band-pass filter;

FIG. 7 is a side sectional view showing an example of three-stage band-pass filter as another embodiment of this invention;

FIG. 8 shows an example of coupling window;

FIG. 9 is a graph showing the coupling coefficient when the coupling window in the shape shown in FIG. 8 is used;

FIG. 10 shows another example coupling window;

FIG. 11 is a graph showing the coupling coefficient when the coupling window in the shape shown in FIG. 10 is used; and

FIGs.12 to 14 are a side sectional view and top views showing an example of resonator having a variable resonance frequency mechanism usable in the filter of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIGs. 3 and 4 are a side sectional view and a perspective view of a semi-coaxial dielectric resonator as a construction

element of a semi-coaxial dielectric filter of this invention. This resonator comprises a dielectric 1 of parallelepiped shape, a cylindrical through-hole 2, a coupling surface 3 having a coupling window 6, an inner conductor 4 of conductive film provided on the wall forming the through-hole 2, an outer conductor 5 of conductive film provided on a side surfaces 7, end surfaces 8 and 9, and a short-circuiting conductor 10 of conductive film provided on the end surface 9.

The dielectric 1 has the through-hole 2 extending in the axial direction, and its one end surface 8 is open while the other end surface 9 is provided with the short-circuiting conductor 10 for short-circuiting, or electrically connecting the inner conductor 4 and the outer conductor 5.

The resonator shown in FIGs. 3 and 4 is a 1/4 wavelength resonator of TEM mode being composed of the inner conductor 4, the outer conductor 5, the short-circuiting conductor 10, and the intervening dielectric 1.

The length ℓ in the axial direction of the resonator is expressed as:

$$\ell = \lambda g/4 \quad , \qquad \lambda g = \lambda o/\sqrt{\varepsilon_r}$$

(λo : wavelength in free space)

(ε_r : dielectric constant)

As is well known, in the 1/4 wavelength resonator, the electric field is intense at the part closer to the open end 8 and the magnetic field is intense at the part closer

to the short-circuiting end 9 in the dielectric 1. The conductive film is very thin, being about tens of micrometers.

FIGs. 5 and 6 show a semi-coaxial dielectric filter constructed by two 1/4 wavelength semi-coaxial dielectric resonators shown in FIGs. 3 and 4. The two resonators 13i and 13o are disposed so that their coupling surfaces 3 having coupling windows 6 contact each other, with the respective outer conductors 5 being electrically connected and mechanically fixed to each other with a solder or a conductive adhesive 14. In this arrangement, the resonators 13i and 13o are coupled with each other via electromagnetic field through the respective coupling windows 6. Supposing the coupling efficiency by electric field coupling to be ke and that by magnetic field coupling to be km, the total coupling efficiency k is expressed as follows:

$$k = |km - ke|$$

As explained above, when the coupling window 6 is disposed closer to the open end surface 8, the total coupling efficiency k is dominated by ke, but on the other hand when it is disposed closer to the short-circuiting end surface 9, km becomes dominant. Input and output terminals 12i and 12o are electrically connected at the open end surfaces 8 to the inner conductors 4 of the resonators 13i and 13o through coupling capacitors 11i and 11o, respectively, thereby constructing the two-stage filter. Each of the

capacitors 11i and 11o may be either a lumped constant or semi-lumped constant capacitor.

The capacitance of the coupling capacitor is expressed as follows:

$$Co \doteqdot Cr \frac{1 + \sqrt{(R/K)^2 - (\omega_o CrR)^2}}{(R/K)^2 - (\omega_o CrR)^2 - 1}$$

The resonator length ℓ' is shorter than the 1/4 wavelength due to the effects of the coupling capacity and the resistances of the terminations at the end of the filter, and expressed as follows:

$$\ell' = (1/4) \cdot (\lambda o/\sqrt{\varepsilon_r}) \cdot (fo/fo')$$

where ...

$\omega_o = 2\pi fo$ fo : center frequency of the filter

$$Cr = \frac{b}{\omega_o}$$

$Lr = \dfrac{1}{\omega_o b}$ b : susceptance slope parameter of of the resonator

$$f' = \frac{1}{2\pi\sqrt{(Lr - Le)\cdot Cr}}$$

$$Le = \frac{Co(Co + Cr)}{\omega_o^2 \cdot Cr \cdot ((\omega_o CoCrR)^2 + (Co + Cr)^2)}$$

R : resistance of the terminations at the ends of the filter

K : impedance-inverter at the ends of the filter

FIG. 7 shows an embodiment of filter in which three

resonators are used. As shown in the figure, in the case of a filter having three or more stages, the inner resonator 13m has two coupling surfaces 3a and 3b which respectively have coupling windows 6a and 6b. Through the respective coupling windows 6a and 6b, the inner resonator is coupled with the resonators 13i and 13o at both sides thereof via electromagnetic field. The capacitance of each of the input and output coupling capacitors 11i and 11o and the resonator length ℓ' of each of the input and output side resonators 13i and 13o are determined by the formulas applied to the embodiment in FIGs. 5 and 6. The resonator length ℓ of the inner resonator 13m is $\ell = \lambda g/4$.

FIG. 8 shows an example of the shape of the coupling window 6. This coupling window 6 is rectangular disposed closer to the short-circuiting end surface 9, and its one side is on the short-circuiting end surface 9. FIG. 9 shows changes in the coupling coefficient k when the width Wl and the length Ll of the coupling window 6 in FIG. 8 are varied, under condition of $\varepsilon_r = 36$, $\ell = 13$ mm, w (width of the resonator) = 10 mm, and a (diameter of the through-hole = 3 mm. If

$$L_1/\ell < 0.5,$$

then km >> ke, thus $k \fallingdotseq km$.

FIG. 10 shows another example of the shape of the coupling window 6. The coupling window 6 is rectangular

one side of which is parallel to the end surface 9, and is isolated on the coupling surface 3. FIG. 11 shows changes in the coupling coefficient k when the length H and the average distance L2 from the end surface 9 of the coupling window 6 in FIG. 10 are varied, under condition of ε_r = 36, ℓ = 13 mm, w = 10 mm, a = 3 mm, and W2 (width of the window 6) = 5 mm.

Considering the results shown in FIGs. 8 to 11, the coupling coefficient k of 0.007 to 0.020 can be achieved by the shape in FIG. 8, and k of 0.015 to 0.035, in FIG. 10. That is, even by mainly using the magnetic field coupling by disposing the coupling window 6 closer to the short-circuiting end surface 9, a sufficient coupling coefficient for composing a filter can be obtained. This is effective to prevent the coupling coefficient from being affected by the environment outside the filter.

FIGs. 12 to 14 show a resonator having a resonance frequency variable mechanism. FIGs. 12 and 13 are a side sectional view and a top view of the resonator, and FIG. 14 is a top view when a dielectric rotor 15 and a shaft 19 are disconnected from the resonator. The inner conductor 4 is electrically connected with the inner conductor open end electrode 17 provided on the open end surface 8. The rotor 15 installed closely to the open end surface 8 has a semi-disk-shaped rotor electrode 16 on its upper

surface which is not opposed to the open end surface 8. An inner part of this rotor electrode 16 is extended to the lower surface of the rotor 15 so as to be in contact with and thus electrically connected with the inner conductor open end electrode 17. On the other hand, an outer conductor open end electrode 18 provided on a part of the open end surface 8 is electrically connected with the outer conductor 5. Therefore, the rotor electrode 16, the outer conductor open end electrode 18 and the dielectric rotor 15 placed therebetween construct a variable capacitor. The rotor 15 is fixed to a shaft 19 which is rotatably inserted into the through-hole. When the rotor 15 is rotated by rotating the shaft 19, the area of the rotor electrode 16 overlapping the outer conductor open end electrode 18 changes, so that the capacitance of the variable capacitor is varied, which permits fine adjustment of the resonance frequency. When a filter is constructed by using the resonators equipped with this resonance frequency variable mechanism, the filter can be easily adjusted.

CLAIMS:

1. A semi-coaxial dielectric filter comprising at least two semi-coaxial dielectric resonators each of which comprises:

a tubular dielectric having a through-hole in its axial direction and at least one flat side surface;

an outer conductor of conductive film provided on side surfaces of said dielectric including said flat side surface;

an inner conductor of conductive film provided on a wall forming said through-hole; and

at least one coupling window provided by removing a part of said outer conductor on said flat side surface;

wherein each of said resonators resonates in TEM-mode in said axial direction by cooperation of said outer and inner conductors and said dielectric intervening therebetween; and

wherein each of said resonators are connected to another by making said flat side surface into contact with that of the another so that said coupling window opposes to that of the another, whereby said resonators are coupled with each other via electromagnetic field through said coupling window.

2. The filter according to claim 1, wherein each of said resonators further comprises a short-circuiting conductor of conductive film provided on at least one end surface of

said dielectric for short-circuiting said outer and inner conductors.

3. The filter according to claim 2, wherein said short-circuiting conductor is provided on only one end of said dielectric, and each of said resonators operates as a 1/4 wavelength resonator.

4. The filter according to claim 3, wherein said coupling window is disposed closer to said end on which said short-circuiting conductor is provided so that said resonators are coupled mainly via magnetic field through said coupling window.

5. The filter according to claim 1, wherein said dielectric has a parallelpiped tubular shape.

6. The filter according to claim 5, wherein said coupling window extends to reach one end surface of said dielectric.

7. The filter according to claim 1, wherein said through-hole has a cylindrical shape.

8. The filter according to claim 1, wherein said coupling window has a rectangular shape.

9. The filter according to claim 1, wherein each of said resonators further comprises: a first electrode provided on one end surface of said dielectric and electrically connected with said outer conductor; a dielectric rotor disposed to oppose to said one end surface of said dielectric; and a second electrode provided on said dielectric rotor

so that said dielectric rotor is intervened between said first and second electrodes, said second electrode being electrically connected with said inner conductor, whereby said first and second electrodes and said dielectric rotor construct a variable capacitor whose capacitance is variable by rotating said dielectric rotor thereby to vary resonant frequency of each of said resonators.

10. The filter according to claim 1, wherein input and output terminals of said filter are extracted through lumped constant or semi-lumped constant capacitors, respectively.

11. The filter according to claim 1, wherein said outer conductor of each of said resonators are electrically connected and mechanically fixed to that of the another with solder or conductive adhesive.

12. A semi-coaxial dielectric filter comprising at least two semi-coaxial dielectric resonators each of which comprises:

a parallelpiped tubular dielectric having a cylindrical through-hole in its axial direction;

an outer conductor of conductive film provided on side surfaces of said dielectric;

an inner conductor of conductive film provided on a wall forming said through-hole;

a short-circuiting conductor of conductive film provided on one end surface of said dielectric for short-

circuiting said inner and outer conductors; and

at least one coupling window which is made by removing a part of said outer conductor of at least one of said side surfaces of said dielectric;

wherein each of said resonators operates as a 1/4 wavelength resonator which resonates in TEM-mode in said axial direction by cooperation of said inner and outer conductors and said dielectric intervening therebetween; and

wherein each of said resonators are connected to another by making said side surface on which said coupling window is provided into contact with that of the another so that said coupling window opposes to that of the another, whereby said resonators are coupled with each other via electromagnetic field through said coupling window.

13. The filter according to claim 12, wherein said coupling window is disposed closer to said end surface on which said short-circuiting conductor is provided so that said resonators are coupled mainly via magnetic field.

14. The filter according to claim 13, wherein said coupling window has a rectangular shape one side of which is parallel to or disposed on said end surface on which said short-circuiting conductor is provided.

15. The filter according to claim 12, wherein each of said resonators further comprises: a first electrode provided on the other end surface of said dielectric and electrically

connected with said outer conductor; a dielectric rotor disposed to oppose to said the other end surface of said dielectric; and a second electrode provided on said dielectric rotor so that said dielectric rotor is intervened between said first and second electrodes, said second electrode being electrically connected with said inner conductor, whereby said first and second electrodes and said dielectric rotor construct a variable capacitor whose capacitance is variable by rotating said dielectric rotor thereby to vary resonant frequency of each of said resonators.

FIG. 1

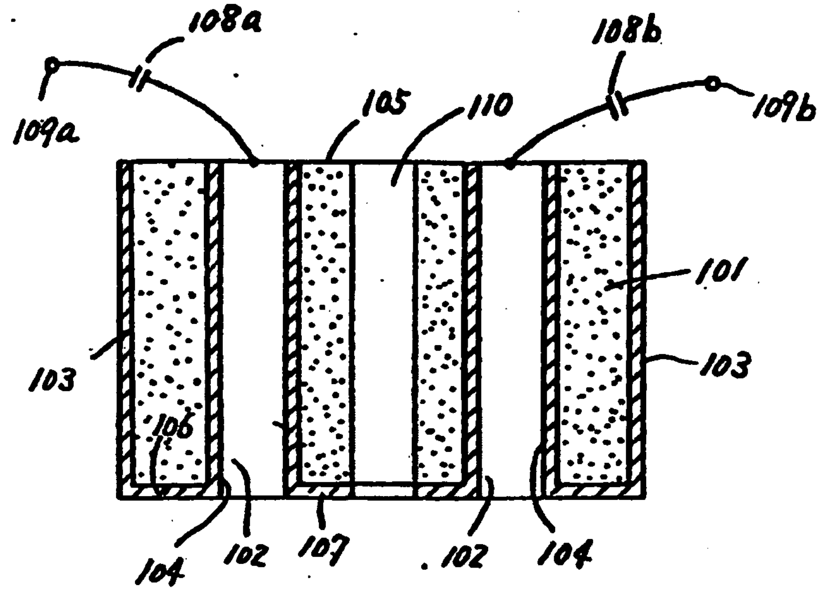
108a
108b
109a
105
110
109b
101
103
103
106
104
102
107
102
104

FIG. 2

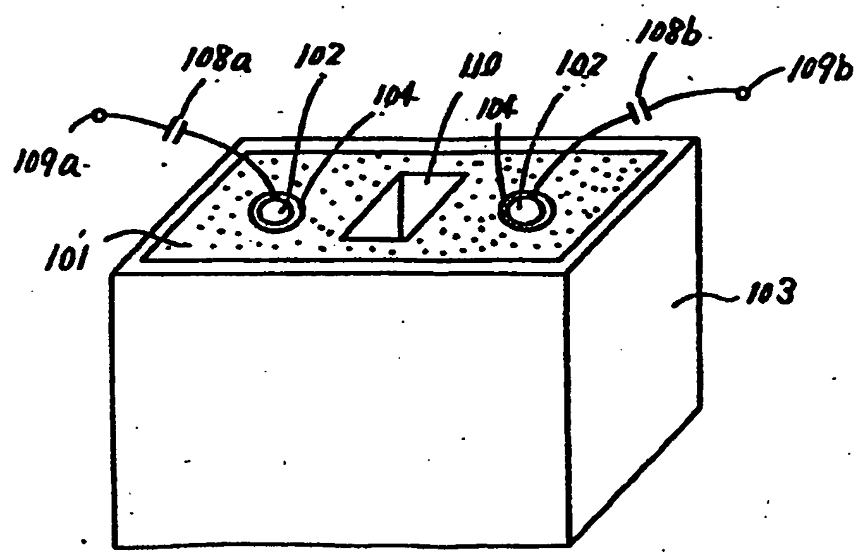
108a
102
104
110
102
108b
109b
104
109a
101
103

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FIG. 3

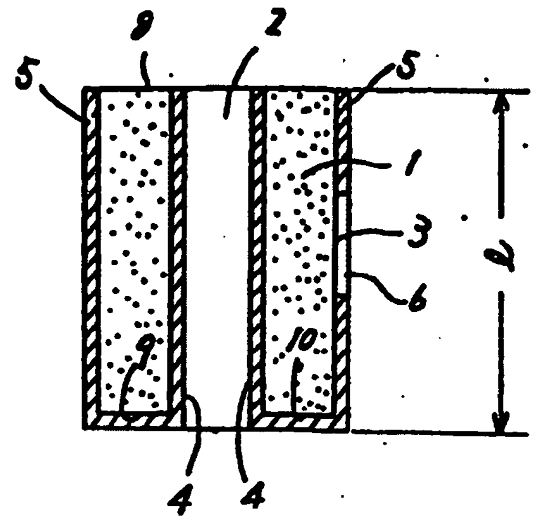


FIG. 4

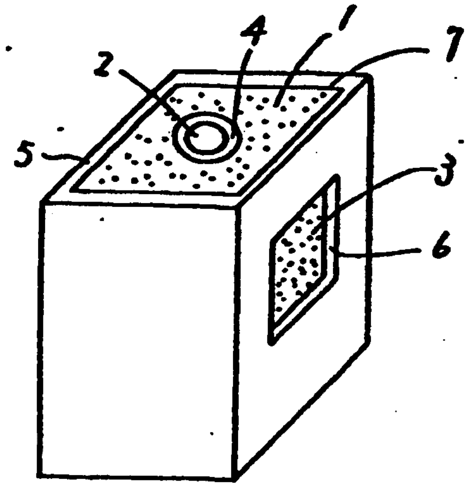


FIG. 5

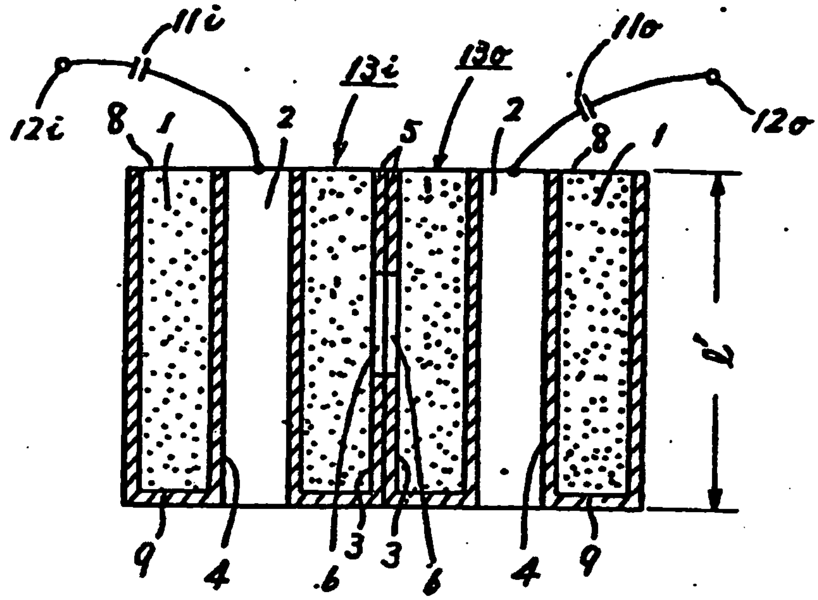
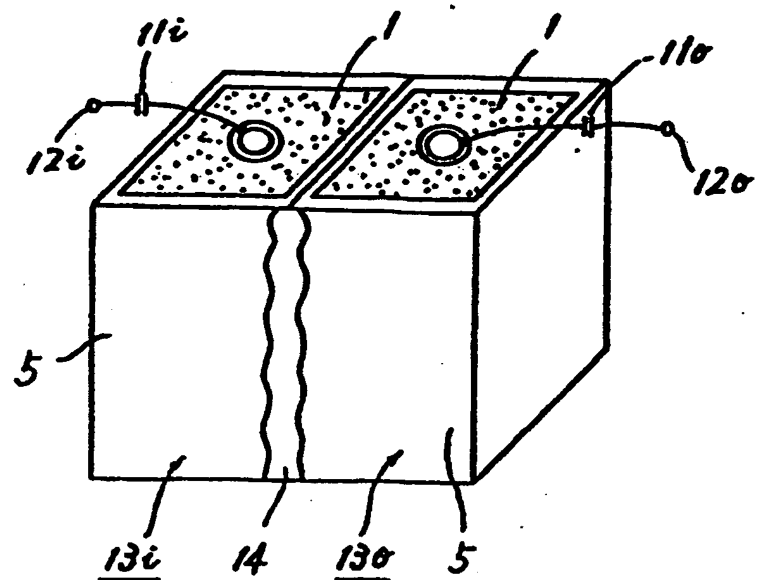

11i
13i
13o
11o
12i
8
1
2
5
2
8
1
12o
l'
9
4
.6
3
3
6
4
9

FIG. 6


11i
1
1
11o
12i
12o
5
13i
14
13o
5

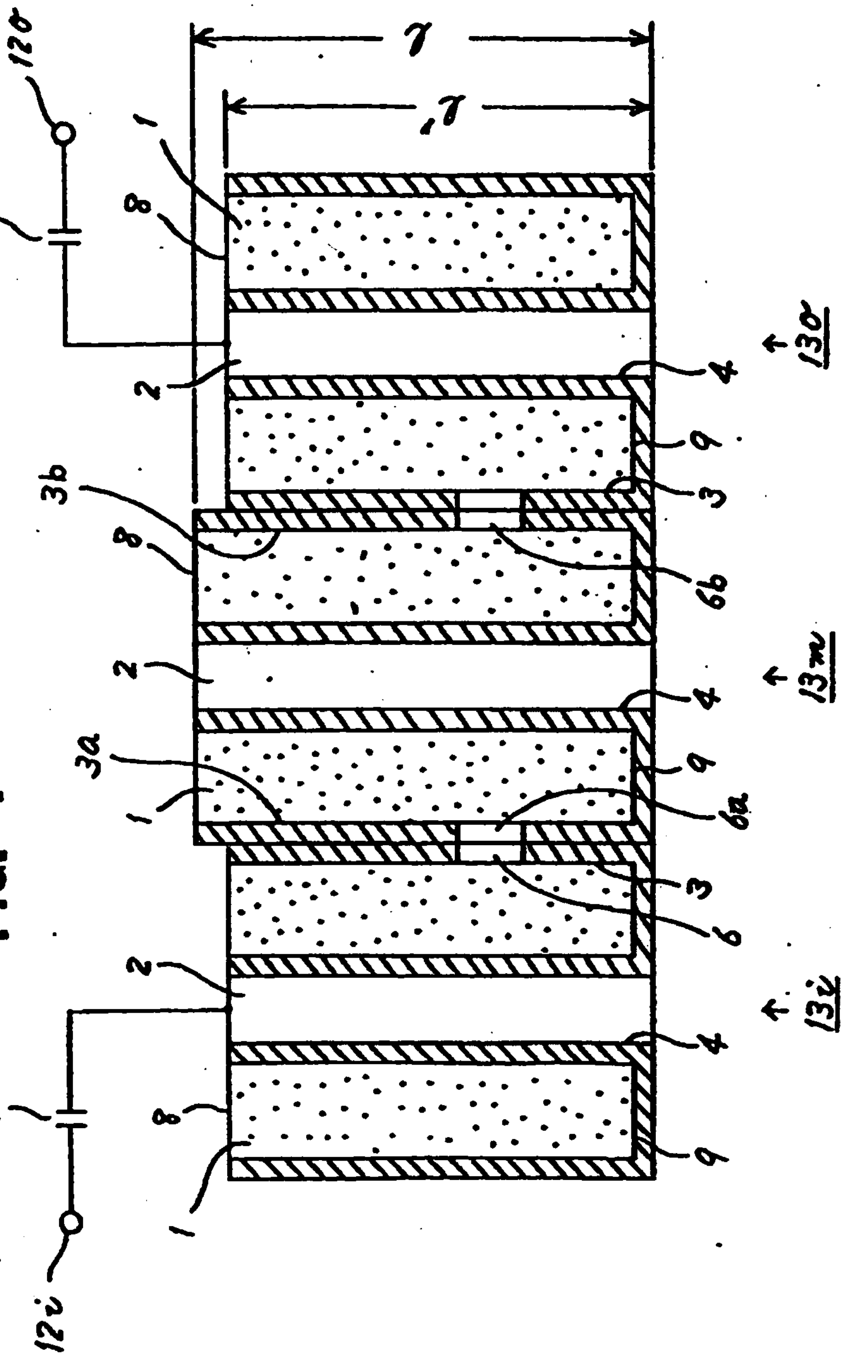


FIG. 7

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FIG. 8

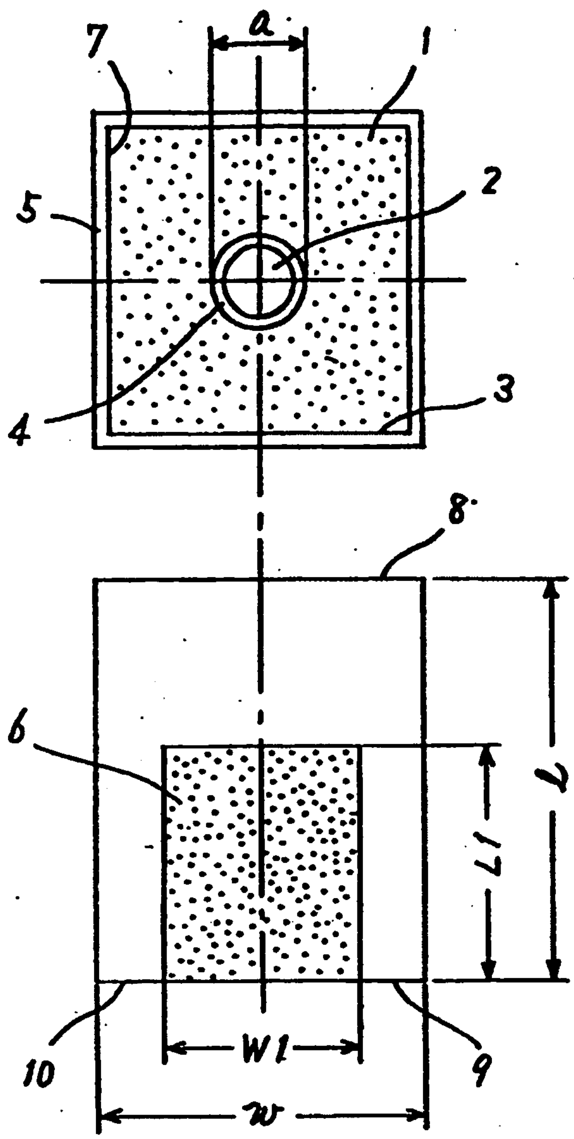


FIG. 9

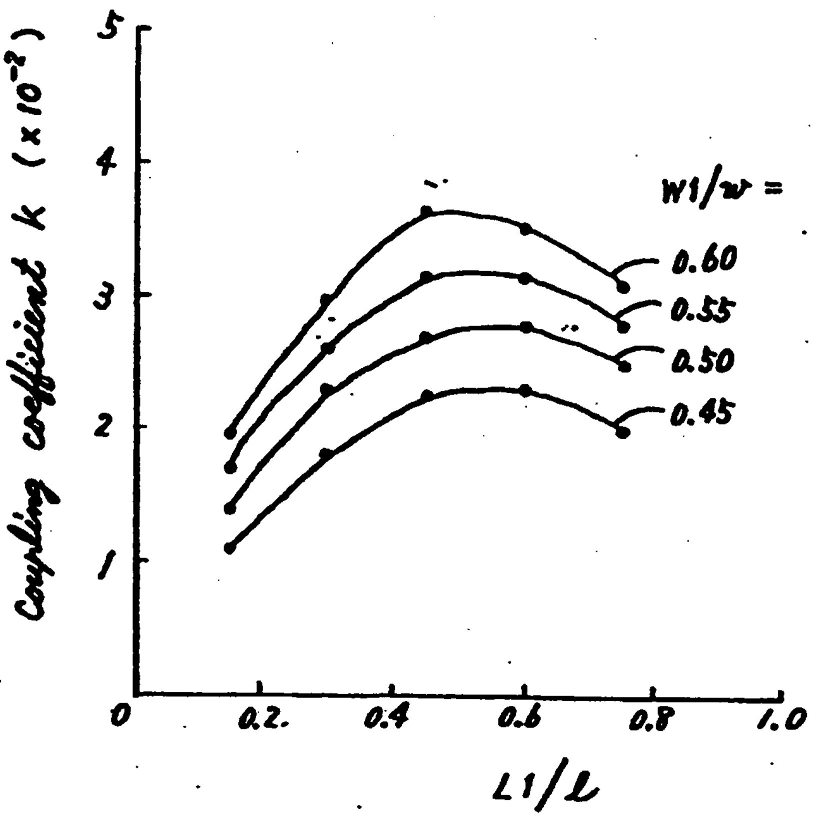

Coupling coefficient k (×10⁻²)
5
4
3
2
1
0
0.2
0.4
0.6
0.8
1.0
L1/l
W1/w =
0.60
0.55
0.50
0.45

FIG. 10

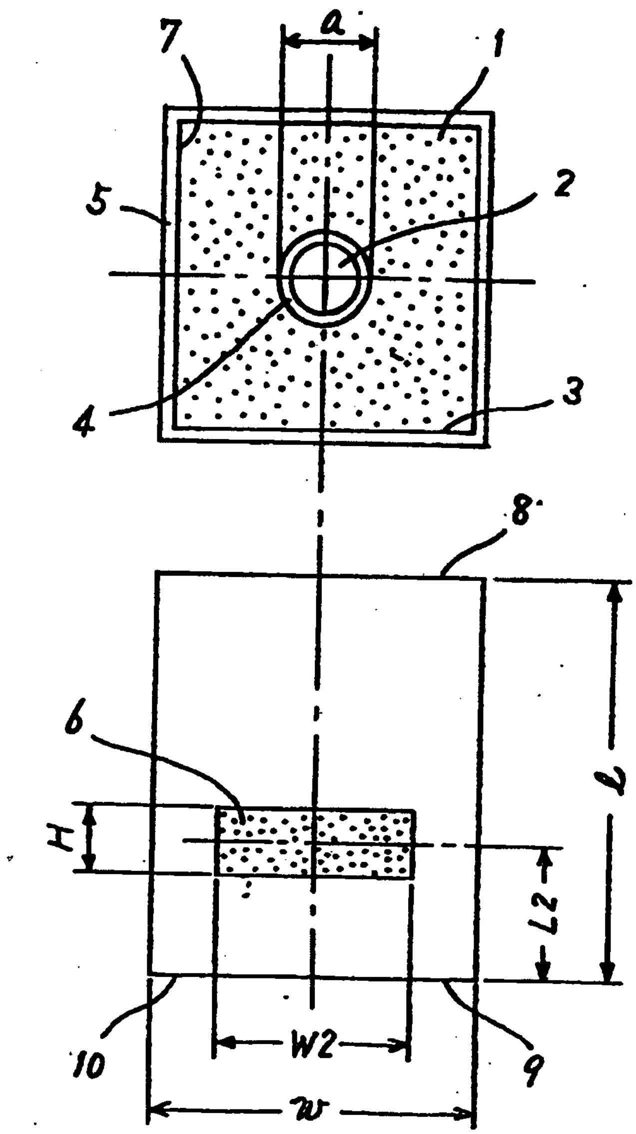


FIG. 11

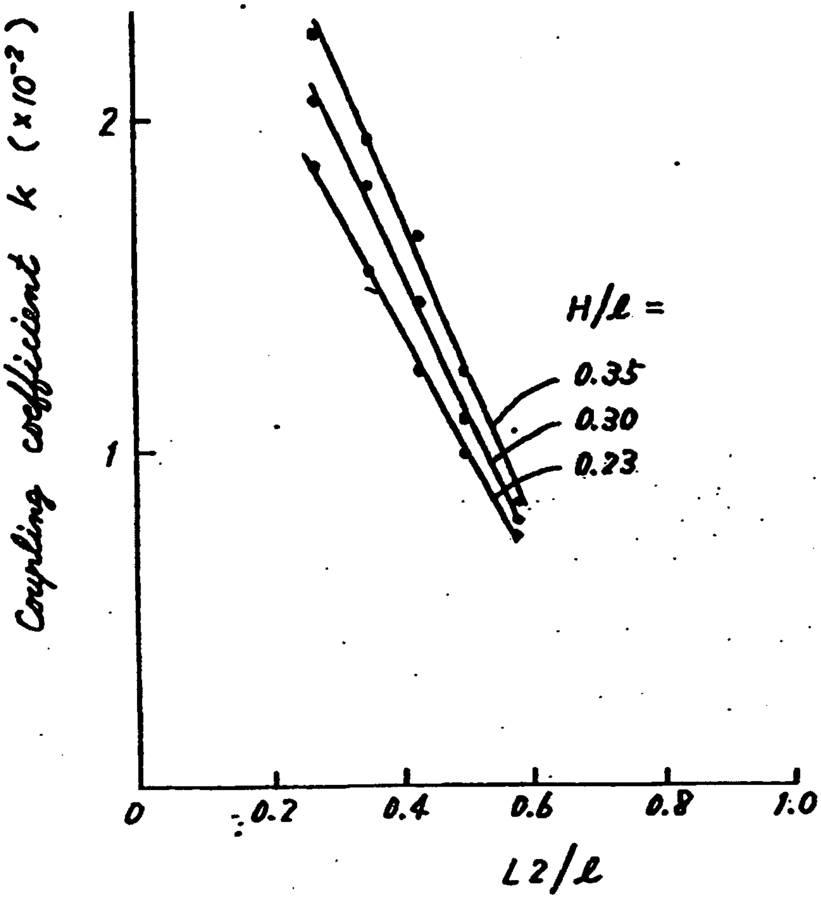

Coupling coefficient k (x10⁻²)
2
1
0
0.2
0.4
0.6
0.8
1.0
L2/ℓ
H/ℓ =
0.35
0.30
0.23

FIG. 12

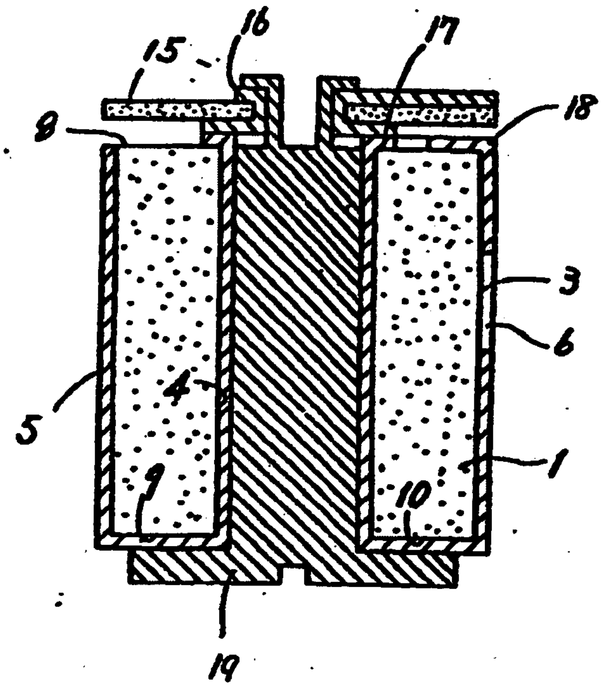


FIG. 13

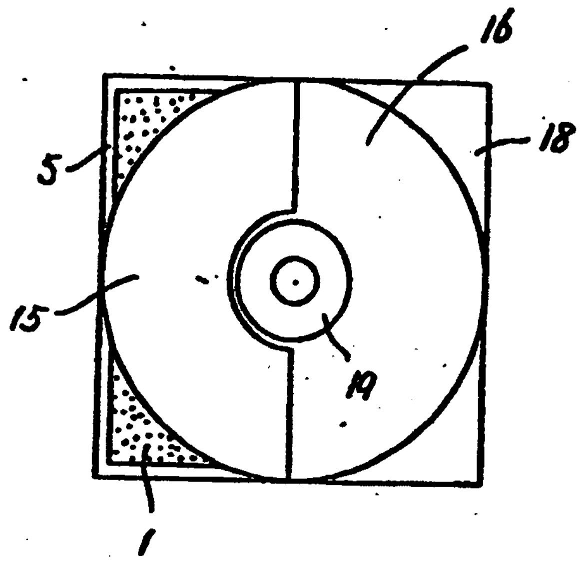
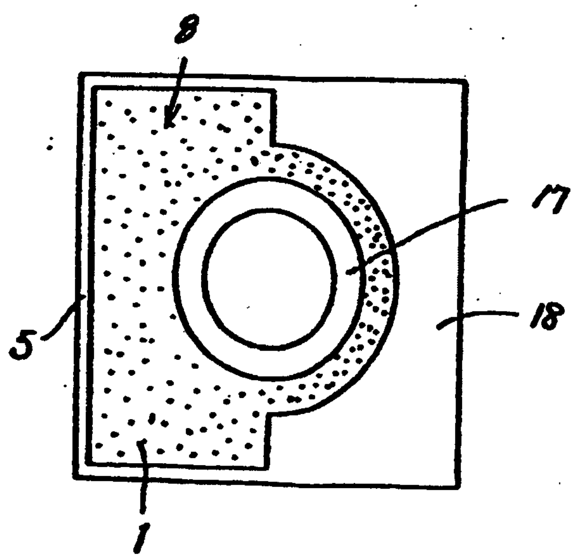


FIG. 14



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EUROPEAN SEARCH REPORT

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EP 86 30 4457

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int Cl.4)
P,X	GB-A-2 163 606 (MURATA) * Abstract; figures 5,6,10-12,17,18,21,22,24 * & FR-A-2 569 496, & DE-A-3 529 810 ---	1-8,10-14	H 01 P 1/205
Y	PATENTS ABSTRACTS OF JAPAN, vol. 6, no. 91 (E-109)[969], 28th May 1982; & JP-A-57 25 701 (TOKYO DENKI KAGAKU KOGYO K.K.) 10-02-1982	1-8,11-14	
A	IDEM ---	9,15	
Y	DE-A-2 805 965 (MURATA) * Page 13, line 16 - page 15, line 21; figures 7-9 * -----	1-8,11-14	TECHNICAL FIELDS SEARCHED (Int Cl.4) H 01 P

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	18-09-1986	LAUGEL R.M.L.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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